(translation)

(12) PATENT LAID-OPEN PUBLICATION (A)

(19) Japanese Patent Office(JP) (11) KOKAI Publication Number TOKKAI 11-68461

(43) Date of Publication: March 9, 1999

(51) Int. Cl.7	Identification Mark	FI	
H 03 B 5/32		H 03 B 5/32	A
G 06 F 1/04		G 06 F 1/04	A

Request for Examination: None
Number of Claims: 2 F D (5 pages in total)

(21) Application Number : 9-228823

(22) Filing Date : August 11, 1997

(71) Applicant : ID NO. 000003104
Toyo Communication Equipment Co., Ltd.
1-1, Koyato 2-chome, Samukawa-machi, Koza-gun,
Kanagawa / Japan

(72) Inventor : Makoto Sugano
c/o Toyo Communication Equipment Co., Ltd.
1-1, Koyato 2-come, Samukawa-machi, Koza-gun,
Kanagawa / Japan

(54) [Title of the Invention] PIEZO OSCILLATION CRICUIT

(57) [Abstract]

To realize a temperature-compensated piezo oscillator capable of high-accuracy frequency temperature compensation by making a temperature compensation voltage controllable in an optional temperature range

[Solution] By using an analog indirect type free of a phase skip as the temperature compensation method and also having included in the compensating voltage generating circuit a plurality of N-th order function generating circuit 2 capable of outputting a DC voltage in an optional temperature range, frequency compensation is made possible in a partial temperature range and a frequency-temperature characteristic with high accuracy is realized.

[Claims]

[Claim 1]

A temperature-compensated oscillator having a voltage-controlled oscillation circuit and a voltage generating circuit for supplying a predetermined compensating voltage to compensate for temperature changes, said temperature-compensated oscillator being adapted to reduce changes in frequency resulting from temperature changes of the voltage-controlled oscillator, wherein said voltage

generating circuit comprises a plurality of N-th order function voltage generating circuits and an adder means for adding outputs thereof.

[Claim 2]

The temperature-compensated oscillator according to Claim 1, wherein at least one of said N-th order function voltage generating circuits constituting said voltage generating circuit is a cubic function generating circuit.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a piezo oscillator, and more particularly to a temperature-compensated piezo oscillator.

[0002]

[Prior Art]

In mobile communication equipment, such as portable phones, demand is increasing more and more in recent years, and small-size crystal oscillators are their key parts as a reference frequency source. In the crystal oscillators used in such mobile communication equipment, as the stability of oscillation frequency in the working temperature range, which is one of the important characteristics, to put it briefly, as the frequency-temperature characteristic, normally, the

stability of ±1 to ±3ppm is required. Generally, it is known that in an AT-cut crystal resonator, its frequency characteristic against temperature changes is approximated by a cubic function. The frequency-temperature characteristic of the crystal oscillator, which uses this crystal resonator as the oscillation source, depends on that of the crystal resonator. Even if an AT-cut crystal resonator known for its high frequency stability among the crystal oscillators is used, it is impossible to limit the frequency-temperature characteristic of the crystal oscillator within ±10ppm in a temperature range of -40℃ to +85℃. Therefore, when a crystal oscillator is used in mobile communication equipment, it is a general practice to use a temperature-compensated crystal oscillator (hereafter referred to as TCXO) including a temperature compensating circuit to flatten the frequency-temperature characteristic of the crystal oscillator.

[0003]

As the temperature compensation method of a TCXO such as mentioned above, the analog indirect type temperature compensation method is well known. As shown in Fig. 4(a), the analog indirect type compensation system involves a voltage-controlled crystal oscillator (hereafter referred to as VCXO) in the oscillation loop as shown in Fig. 4(a), the VCXO oscillator including a variable reactance circuit capable of

changing, by a control voltage, the reactance value of a variable capacitance diode, for example, and the VCXO supplies a voltage changing as a cubic-function, derived from a circuit network formed by resistors and thermistors as shown in Fig. 4(b), to both ends of the variable reactance circuit. More specifically, the crystal oscillation circuit is so configured to give cubic-function-like reactance changes against temperature changes in the oscillation loop and compensates the frequency-temperature characteristic as the crystal oscillation circuit so as to be within predetermined values.

[0004]

[Problem to be solved by the Invention]

In a conventional analog indirect type TCXO, no matter how the temperature compensation voltage generating circuit is adjusted due to variations of the temperature detection characteristic of the thermistor elements or owing to the temperature characteristic of the resistor elements or the like, which constitute the temperature compensation voltage generating circuit, it is impossible to completely flatten the frequency-temperature characteristic of the crystal resonator. The limit values of the frequency-temperature characteristic of the TCXO of the analog indirect type compensation system are generally within ±1.0ppm/about -30℃ to +85℃. If much better stability is required, it has been necessary to use digital

temperature compensation or an oven-controlled crystal oscillator. Digital temperature compensation uses a compensation circuit which is configured such that ambient temperature information is converted into a digital signal, and by this signal, a control voltage code is read from the memory device where control voltage codes are stored associated with corresponding temperatures, and based on the control voltage code, a control voltage is generated which is to be supplied to the voltage-controlled oscillator. However, since temperature compensation voltage is changed according to digitized temperature information, the temperature compensation voltage changes in a discontinuous, staircase pattern, with respect to the change of ambient temperature. If this temperature compensation voltage is applied to a variable reactance element, a problem of "phase skip" occurs that the oscillation frequency instantaneously changes in contrast to temperature change. Therefore, if a TCXO with such a characteristic is used on a mobile communication device, a discontinuity occurs during communication or erroneous data is transmitted, for example. Meanwhile, the above-mentioned oven-controlled crystal oscillator has a highly stable frequency-temperature characteristic and is free of "phase shift" in frequency, but because it is necessary to heat the inside of the oven to about +70℃ to +90℃, required power

consumption is several tens to several hundreds times larger than in the TCXO. In addition, since the oven-controlled crystal oscillator is large in size and expensive, it is impossible to use it in a small-size inexpensive mobile communication unit.

[0005]

The present invention solves the above-mentioned problems, and has its object to provide a TCXO, which has a highly stable frequency-temperature characteristic and which is free of "phase shift" and easy to miniaturize compared with a conventional analog indirect compensation TCXO.

[0006]

[Means for solving the Problems]

For the frequency-temperature compensation system, an analog compensation system free of "phase shift" of oscillator frequency with respect to temperature changes is adopted in this invention, and in this analog category, the analog indirect compensation system is selected which uses a temperature compensation voltage generating circuit, including an N-th order function generating circuit capable of achieving temperature compensation of oscillator output frequency in an optional temperature range without using thermistor elements having no possibility of being integrated. Furthermore, to improve temperature compensation accuracy, the temperature

compensation voltage generating circuit is used, which includes a plurality of the above-mentioned N-th order function generating circuits capable of outputting a DC voltage in an optional temperature range. The TCXO is formed to achieve frequency temperature compensation by applying a DC voltage output from the temperature compensation voltage generating circuit to the variable reactance element in the oscillation loop.

[0007]

[Mode for Carrying Out the Invention]

Detailed description will be made of the present invention with reference to an embodiment. Fig. 1 is a block diagram of an embodiment showing a block circuit of a TCXO using a temperature compensation voltage generating circuit according to the present invention. The TCXO 5 in Fig. 1 includes a temperature sensor 1, a voltage generating circuit block 2 including a plurality of N-th order function generating circuits (2-1, 2-2, ... 2-n), an adder circuit 3, and a voltage-controlled crystal oscillator (VCXO) 4, wherein output of the temperature sensor 1 is input to a plurality of N-th order function generating circuits (2-1, 2-2, ... 2-n). The TCXO 5 in Fig. 1 is formed such that outputs of the plurality of N-th order function generating circuits (2-1, 2-2, ... 2-n) are passed through the adder circuit 3 to a control voltage input

portion of a VCXO 4. In the example of Fig. 1, the VCXO 4 is set so as to output a specific frequency of f0 when a DC voltage input to the control voltage input portion at a normal temperature is +2V. Fig. 2 (a) shows an example of a frequency voltage characteristic of the TCXO 5 under the condition that the control voltage of the VCXO 4 is constant at +2V in Fig. 1, in which the horizontal axis indicates temperature and the vertical axis indicates frequency deviation under a condition that the control voltage of the VCXO 4 in Fig. 1 is +2V. In other words, this figure shows the condition without a temperature compensation function, in which the frequency temperature characteristic of the crystal resonator is reflected as it stands and its curve is formed in a manner of a cubic function, when the normal temperature is set at a temperature of the inflection point, a maximum value is present in a temperature range below the normal temperature, and a minimum value is present in a temperature range above the normal temperature. Fig. 2(b) shows an example of a frequency control voltage characteristic depicting changes of oscillation frequency accompanying changes of controlled voltage value in the VCXO 4 in Fig. 1, in which the horizontal axis indicates control voltage values and the vertical axis indicates frequency deviations. From this graph, it is understood that as the control voltage increases, the frequency of the VCXO 4

rises in a linear function. Fig. 2(c) shows an example of a temperature compensation voltage characteristic depicting output voltage values versus temperature of the N-th order function generating circuit 2-1 in Fig. 1, in which the horizontal axis indicates temperature and the vertical axis indicates compensating voltage. The temperature compensating voltage characteristic is such that when normal temperature is set at a temperature of inflection point, a minimum value of less than +2V is present in a temperature range below normal temperature and a maximum value of more than +2V is present in a temperature range above normal temperature.

[0008]

Also, it is supposed that the other N-th order function generating circuits (2-2, 2-3, ... 2-n) are not outputting anything or outputting 0V. The frequency-temperature characteristic of the TCXO 5, when a temperature compensation voltage shown in Fig. 2(c) is input to the control voltage input of the VCXO 4, shown in Fig. 1, which has characteristics of Figs. 2(a) and 2(b), cannot fully offset deviations in temperature ranges from A′ to A, from B′ to B, and from C′ to C shown in Fig. 2(d). This corresponds to a compensation limit condition in the analog indirect compensation system in prior art. To further stabilize the frequency temperature characteristic shown in Fig. 2(d), it is only necessary to input

a correcting compensation voltage as shown in Fig. 3(e) to the control voltage input of the VCXO 4 to offset deviations of frequency characteristics in temperature ranges from A′ to A, from B′ to B, and from C′ to C shown in Fig. 2. Meanwhile, the characteristic of Fig. 3(e) can be obtained from Figs. 2(b) and 2(d). The correcting compensation voltage as shown in Fig. 3(e) can be expressed by a plurality of function equations. In this example, to make the effect of the present invention easy to understand, the correcting compensation voltages are applied in a second order function form for a temperature range of A′ to A, in a cubic function form for a temperature range of B′ to B, and in a linear function form for a temperature range of C′ to C. The three correcting voltages are output from different N-th order function generating circuits. Fig. 3(f) shows a correcting compensation voltage output from the above-mentioned N-th order function generating circuit 2-2 for a temperature range of A′ to A of Fig. 2(d), Fig. 3(g) shows a correcting compensation voltage output from the N-th order function generating circuit 2-3 for a temperature range of B′ to B of Fig. 2(d), and Fig. 3(h) shows a correcting compensation voltage output from the above-mentioned N-th order function generating circuit 2-4 for a temperature range of C′ to C.

[0009]

Correcting compensation voltages output from the N-th

order function generating circuits (2-2, 2-3, 2-4), after added with a correction voltage output from the N-th order function generating circuit 2-1 by the adder circuit 3 as shown in Fig. 1, are input to the control voltage input portion of the VCXO shown in Fig. 1; therefore, the frequency-temperature characteristic of the TCXO 5 shown in Fig. 1 becomes highly stable (within ±0.5ppm/-30℃ to +85℃, for example) as shown in Fig. 3(i). Meanwhile, in embodiments of the present invention, as the oscillator's piezo element, the AT-cut crystal resonator has been used, but the present invention is not limited to this configuration, and the present invention can be applied to various piezo elements by adjusting output of the N-th order function generating circuits shown in Fig. 1 by using not only a cubic function but any other functions.

[0010]

[Effect of the Invention]

A temperature compensation type piezo oscillator including a temperature compensation voltage generating circuit according to the present invention is free of "phase skip" that occurs in a digital system because this oscillator is of an analog compensation system. Because the above-mentioned temperature compensation voltage generating circuit includes a plurality of N-th order function generating circuits to make it possible to output a DC voltage in any temperature range,

this temperature compensation piezo oscillator can realize a frequency-temperature characteristic with much higher stability than in temperature compensation type piezo oscillators of prior art. Furthermore, the temperature compensation voltage generating circuit according to the present invention, because it does not use thermistor elements, provides chances of integration and further miniaturization of the oscillator.

[0011]

[Brief Description of the Drawings]

Fig. 1 a block diagram of an embodiment of the TCXO according to the present invention;

Fig. 2(a) shows the oscillator's frequency-temperature characteristic before compensation;

Fig. 2(b) shows a frequency control voltage characteristic of the VCXO;

Fig. 2(c) shows compensation voltage of an N-th order function generating circuit 2-1;

Fig. 2(d) shows a frequency-temperature characteristic of the TCXO;

Fig. 3(e) shows correcting compensation voltage;

Fig. 3(f) shows correcting compensation voltage by an N-th order function generating circuit 2-2;

Fig. 3(g) shows correcting compensation voltage by an N-th

order function generating circuit 2-3;

Fig. 3(h) shows correcting compensation voltage by an N-th order function generating circuit 2-4;

Fig. 3(i) shows a frequency-temperature characteristic of the TCXO according to the present invention;

Fig. 4(a) is a configuration diagram of an analog indirect temperature compensation oscillator block of prior art; and

Fig. 4(b) shows an example of the compensation voltage generating circuit.

[Description of Codes]

1 ... Temperature sensor

2 ... Voltage generating circuit block

(2-1, 2-2, 2-3, ... 2-n) N-th order function generating circuits

3 ... Adder circuit

4 ... Voltage-controlled crystal oscillator (VCXO)

R1, R2, R3 ... Resistor elements

THR1, THR 2 ... Thermistor elements

FIG. 1

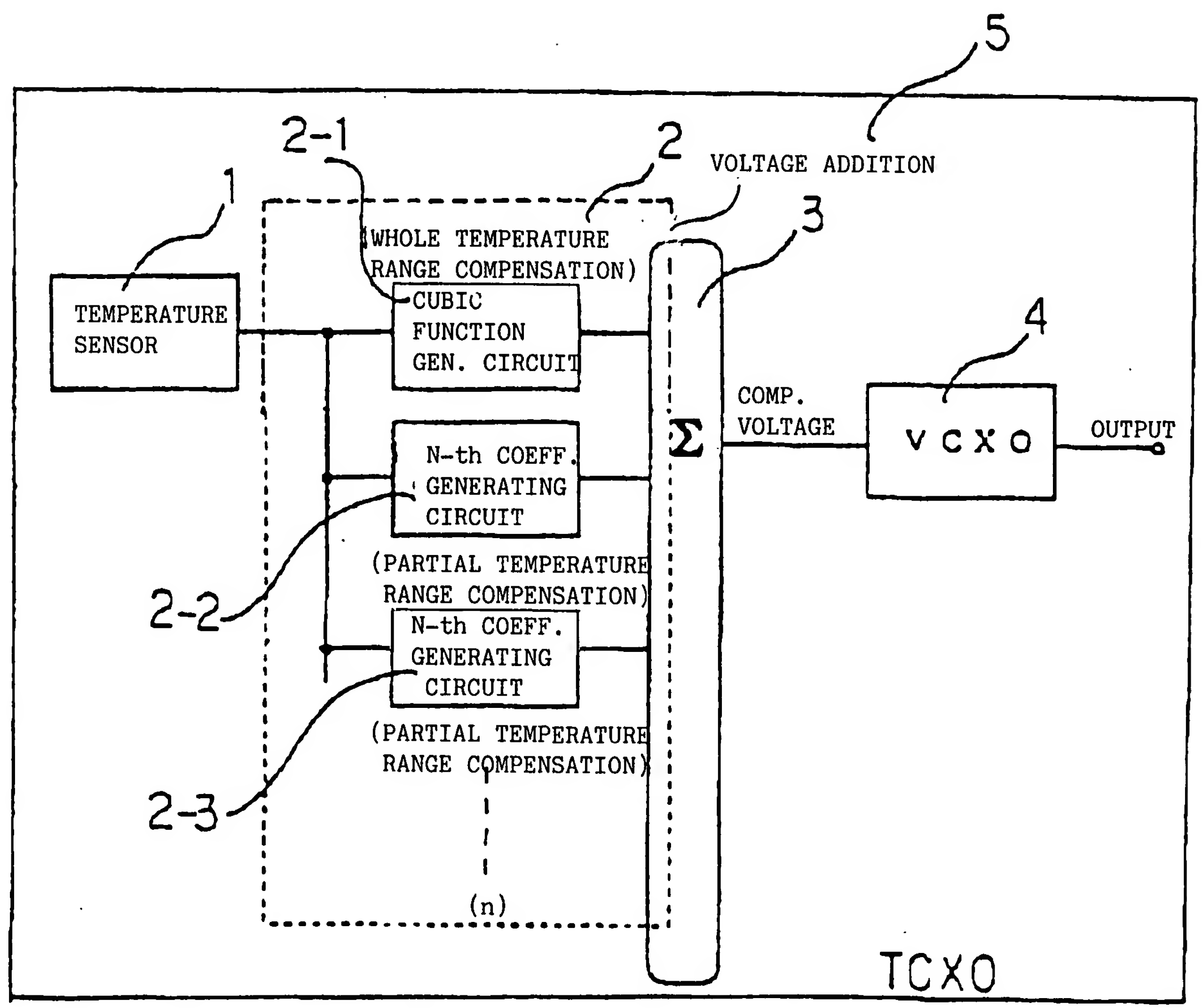
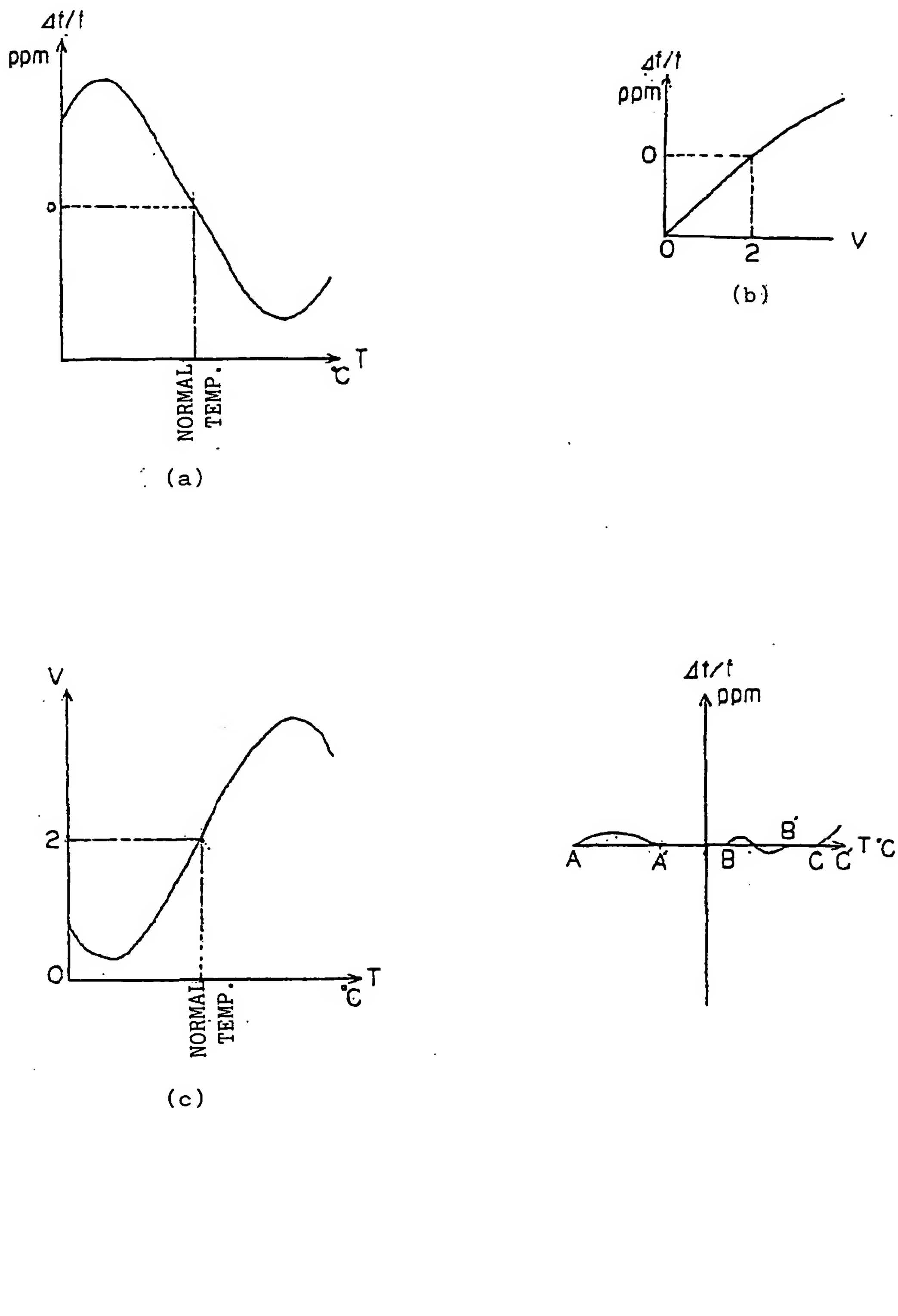

5
VOLTAGE ADDITION
2-1
2
3
1
TEMPERATURE
SENSOR
(WHOLE TEMPERATURE
RANGE COMPENSATION)
CUBIC
FUNCTION
GEN. CIRCUIT
N-th COEFF.
GENERATING
CIRCUIT
(PARTIAL TEMPERATURE
RANGE COMPENSATION)
N-th COEFF.
GENERATING
CIRCUIT
(PARTIAL TEMPERATURE
RANGE COMPENSATION)
(n)
2-2
2-3
Σ
COMP.
VOLTAGE
4
VCXO
OUTPUT
TCXO

FIG. 2



Δf/f
ppm
o
T
°C
NORMAL
TEMP.
(a)
Δf/f
ppm
0
0
2
V
(b)
V
2
O
T
°C
NORMAL
TEMP.
(c)
Δf/f
ppm
A
A'
B
B'
C
C'
T°C

FIG. 3

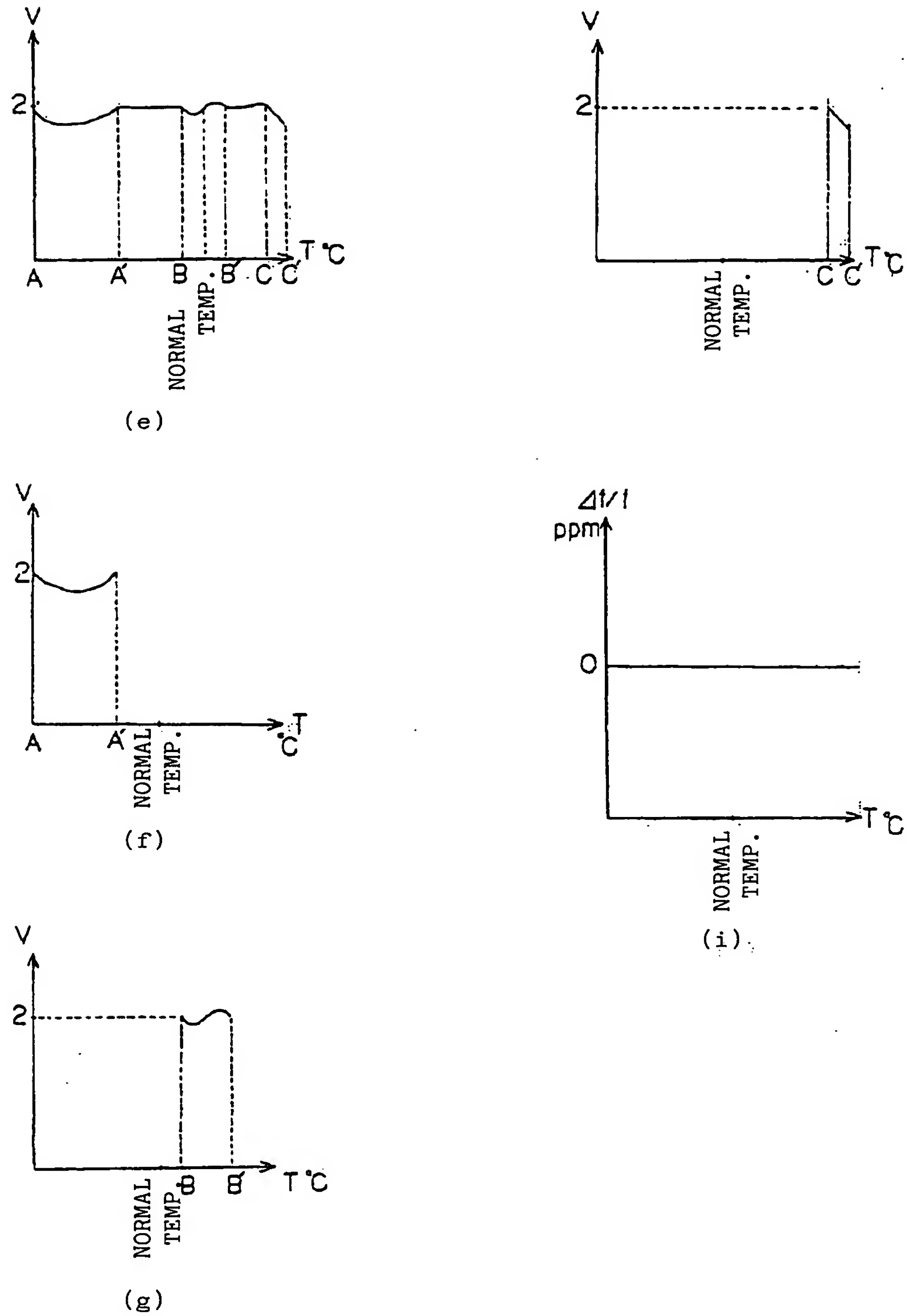
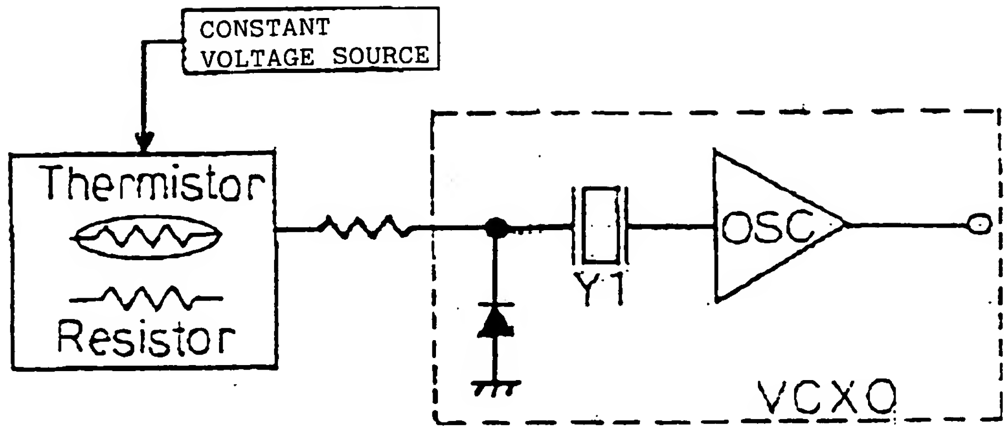
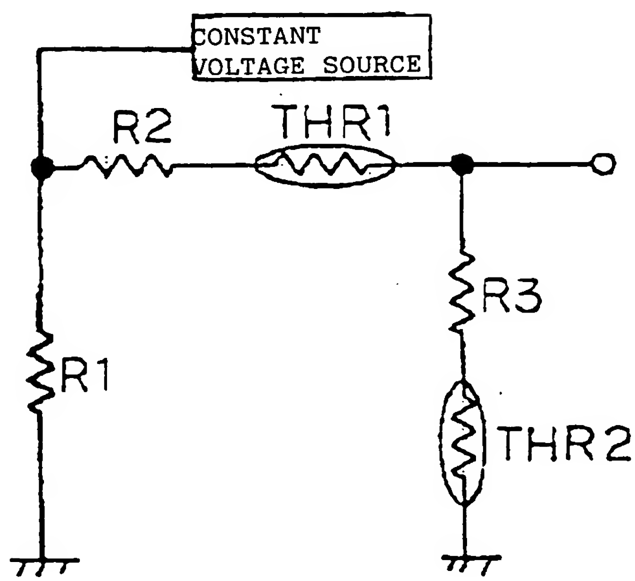

V
2
A
A'
B
B'
C
C'
T ℃
NORMAL TEMP.
(e)
V
2
C
C'
T ℃
NORMAL TEMP.
V
2
A
A'
T ℃
NORMAL TEMP.
(f)
Δf/f ppm
0
T ℃
NORMAL TEMP.
(i)
V
2
B
B'
T ℃
NORMAL TEMP.
(g)

FIG. 4


CONSTANT
VOLTAGE SOURCE
Thermistor
Resistor
Y1
OSC
VCXO


CONSTANT
VOLTAGE SOURCE
R2
THR1
R3
R1
THR2